Engineering Study of the Coals
On the Chicago Market

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THESIS:- AN ENGINEERING STUDY OF THE COALS

ON THE CHICAGO MARKET.

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Accepted.

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The samples of coal for analysis were very kindly
presented to the writer by the City Fuel Co., since purchased
by the Peabody Coal Co., whose yards are located at Wentworth
Avenue and 40th Street., Chicago.   The samples were taken from
the different coal piles around the yards one warm day in Feb-
ruary and were quite wet from the melted snow so that it was
thought advisable to allow them to stand for a couple of weeks
before grinding for analysis, in order that any undue moisture
which might have been absorbed by the coal during its exposure
to the snow and water, might dry out normally.   Although it is
preferable to take large samples and quarter them down to the
amount desired for analysis, it was not done in this case owing
to lack of working and storage space.   However, two or three
small lumps having as near the average composition of the pile
as could be told by inspection, were taken, and the state and
district from which each coal came noted.   The most of the sam-
ples taken came from Illinois, Pennsylvania and West Virginia,
in which states, by the way, the largest share of the coal of
the United States is mined.   In 1900, Pennsylvania ranked first
in coal production, Illinois second, and West Virginia third.

After having been air-dried for a couple of weeks,
each sample was prepared for analysis by crushing with a hammer
and grinding as finely as possible in a small coffee mill.
This reduced the sample to particles somewhat smaller than a
pin head.   The samples, when ground, were placed in glass bot-
tles with tight fitting corks to prevent them losing any mois-
ture to the air, it having been found that a finely divided
coal left exposed to the air, will lose its moisture in a short

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time. The moisture determinations were made by drying one
gram of the sample over sulphuric acid for from four to ten
days. The most of the moisture will leave a coal in about
three hours when dried over sulphuric acid, while after four
days drying, no increase in the per cent of moisture can be
noted. From data obtained by W. F. Hillebrand, samples dried
in vacuo over sulphuric acid, give higher and probably more
nearly correct results, than either drying in the air over sul-
phuric acid, or drying in an oven at 105° for an hour.

The dried sample was used for the determination of
volatile combustible matter. It was transfer͟r͟ed to a platinum
crucible having a closely fitting cover and heated in the full
flame of a Chaddock burner for exactly seven minutes. The up-
per surface of the cover burned clear but the lower surface was
black with carbon. The loss in weight was volatile combustible
matter. This determination is, at best, only arbitrary, the
results varying as much as ten or twelve per cent with differ-
ent operators. It is very hard to make the determination under
constant conditions for several samples, different lamps often
giving widely varying results. I think I reduced the liabil-
ity to error from the lamp to a minimum by using a Chaddock
burner and taking care to run duplicates as closely together as
possible, using the same lamp and flame. One serious object-
ion to this method is the danger of mechanical loss at the com-
mencement of the heating, but it is thought that there is less
danger of error from this source than would arise from any
other method yet proposed.

After weighing, the carbon left in the crucible was
burned down to an ash over a blast flame.   An objection to
using this caked carbon for the determination has been raised
on account of its taking so much longer to burn down than a
fresh sample, but I found that by leading a slow steam of air
into the crucible, the carbon was reduced to ash as quickly as
a fresh sample, and thus the time required to weigh out a new
sample was saved.

The Parr Standard Calorimeter was used for the de-
termination of the calorific value of the samples taken.   A
brief description of the instrument will be given here.   Re-
ferring to the blue print, Fig. II shows the calorimeter assem-
bled, and Fig. I shows the cartridge.   A (Fig. II) is a metal can
of a little more than two liters capacity which is insulated
from the air by the two paper jars BB and CC.   These jars have
an air space between them and are held together by bolts pass-
ing through the corks KK.   A deflecting collar EE carrying the
brass pivot F stands in the bottom of the can AA.   The car-
tridge D rests upon the pivot and is rotated by means of the
pulley P, the power being furnished by a small water motor.
The vanes fasten ed to the cartridge by means of spring clips,
deflect the water currents downward if the cartridge is turned
clock wise, as it should be.   The cartridge is made of brass.
The stem contains a channel for the passage of the wire fuse
required for ignition.   The fuse is dropped through the cap E
(Fig. I) and held by the valve D until it is released by press-
ing down upon E.   A coiled spring keeps the valve D closed
when it is not held down by pressure upon E.   A determination

of the calorific value of a coal is made as follows.   First place
the thermometer near the calorimeter and allow it to remain a
few minutes to get the room temperature.   During this period,
the cartridge may be charged.   First place one measureful of
sodium peroxide in the cartridge.   Then add exactly 1/2 gram
of the coal which has been pulverized to pass a 100 mesh sieve
and dried, either over sulphuric acid in a dessicator for 24
hours, or at 105° C in an oven for an hour.   Screw the top and
stem on firmly and shake vigorously holding the thumb on the
cap E to keep any of the charge from getting under the valve D.
Tap the cartridge on the desk to settle the charge.   Next,
having determined the temperature of the room, place exactly
two liters of water which is at a temperature from 2° to 4° be-
low room temperature, in the can A having first seen that the
deflecting collar and pivot are in place.   Set the cartridge
carrying the vanes, upon the pivot and cover the calorimeter.
The thermometer is then placed in position with the bulb about
half way up from the bottom of the can A, a rubber collar keep-
ing it from slipping, and the cartridge rotated at from 50 to
100 R.P.M. for a short time before igniting the charge, in order
to obtain a constant temperature.   The initial temperature
having been taken, the charge is ignited by dropping a piece of
red-hot copper wire 3/8 of an inch long into the stem of the
cartridge and pressing down the valve, releasing it as quickly
as possible.   The rapid rising of the mercury indicates that
the charge has been successfully ignited.   In about five min-
utes, the maximum temperature will have been reached, and from
the rise in temperature, the calorific value is obtained as
follows:

Sample "C"

Initial Temperature - - 68.65°

Final   "   - - 73.10°

Rise in   "   - -   4.45°

Corrected for the hot wire

by subtracting .022   -   4.428°

4.428 X 3100 = 13726.8 B.T.U. per pound of coal.

"The factor 3100 is deduced as follows: The water used plus the water equivalent of the metal in the instrument amounts to 2123.5 grams.   In the reaction 73% of the heat is due to combustion of the coal and 27% is due to the heat of combinaton of CO_2 and H_2O with the chemical.

If now 1/2 gram of coal causes 2123.5 grams of water to rise r degrees, and if only 73% of this is due to combustion, then - 0.73 X 2123.5 X 2 X r equals the rise in temperature that would result from the combustion of an equal weight (2123 grams) of coal.

0.73 X 2123.5 X 2 = 3100.

The rise in temperature would of course, be the same for any other quantities of coal and water that were equal in amount - as one pound of coal and a pound of water - hence the 'British thermal units per pound of coal' "   Bates - Calorimetry, P.86.

Note:- The charge must be thoroughly shaken in order to insure complete combustion, as I found that when the charge was only slightly shaken or was left in layers, the combustion was very incomplete, the inside of the cartridge being black with carbon.

The determination of sulphur was made from the ash of the sample used in making the calorimetric test. The sodium peroxide and ash were dissolved out of the cartridge with hot water and the solution acidified with hydrochloric acid, when a clear solution was obtained. A slight excess of ammonium hydroxide was then added and the iron and alumina which precipitated out were filtered off. The solution was again made acidic with hydrochloric acid, heated to boiling, and hot barium chloride added, the sulphur precipitating out as barium sulphate. The solution was then either boiled for half an hour or allowed to stand over night, which ever was the most convenient, in order to digest the precipitate to keep it from going through the filter paper, and the barium sulphate filtered off on an ashless filter paper, washed thoroughly, dried, ignited and weighed. The amount of sulphur present was then determined from the proportion, 1mg. of barium sulphate containes 0.14 mg. of sulphur. This should be a very good method for determining the total sulphur in a coal as it is impossible for any of the products of combustion to escape from the cartridge, and even though the combustion of the coal may be incomplete, the sulphur will all go off at a lower temperature than that required for the complete combustion of the sample. Care must be taken to set the cartridge in a large beaker - #6 is the best - and cover it with a watch glass before starting to dissolve out the contents, as a great spattering is set up the minute the hot water is introduced into the cartridge, due to the violent reaction between sodium peroxide and water. The hot water should be shot into the cartridge from a wash bottle,

the tip of the bottle being introduced under the watch glass over the lip of the beaker, thus doing away with the necessity of raising the watch glass.

Sulphur is detrimental in a steaming coal principally on account of the corrosive effect of its products of combustion on grate bars and other iron surfaces with which they may come in contact.   Also, for most metallurgical processes, coal should be relatively free from sulphur.

The sum of the moisture, volatile combustible matter and ash, subtracted from 100 gives the per cent of fixed carbon, without any correction for sulphur, however.   It is believed that half of the sulphur goes off with the volatile combustible matter and half of it stays with the fixed carbon. Therefore, the results of both the determination of volatile combustible matter and the determination of fixed carbon were corrected for sulphur and both the original and corrected results were tabulated.

"The various fuel requirements call for coals of varying composition, and the adaptability of any coal to a particular purpose is determined largely by the relative abundance of the several fuel constituents."   These fuel constituents are the volatile combustible matter and the fixed carbon, and their relation is called the fuel ratio.   This quantity is obtained by dividing the per cent of fixed carbon by the per cent of volatile combustible matter in the coal and is very useful in determining whether or not a coal will fulfill the requirements of the purpose for which it is to be used.   Up to a certain point the fuel value or heating power of a coal increases with

the fuel ratio, the combustion of the carbon developing more
heat than the combustion of the volatile matter; but beyond
this point, th difficulty of effecting combustion more than
makes up for the greater amount of heat obtained.

   This point is well illustrated by Sample "B", a Penn-
sylvania anthracite. The fuel ratio is very high being 18.711.
Repeated trials under all sorts of conditions failed to ignite
the charge in the colorimeter cartridge. The charge was put
in in layers of sodium peroxide and coal, the top layer being
coal, and in layers with the top layer peroxide, but the hot-
test fuse failed to ignite it. The same charge was then thor-
oughly shaken and another fuse added but to no avail. A
charge was then made by placing all the peroxide in the car-
tridge and then all the coal, and shaking thoroughly but no ig-
nition took place upon the addition of the fuse. All the other
samples with the exception of one or two, ignited with the
first fuse and gave good complete combustion if the charge had
been thoroughly shaken. In no case was more than two fuses
needed to ignite the charge.

   Besides the fuel constituents of a coal, there are
others which are non-essential, the two of most importance be-
ing ash and moisture. The latter replaces volatile combustible
matter, requires heat for its volatilization and also causes a
coal to break up into fine particles as it dries out. Hence,
an excessive amount of water is detrimental to a coal. The
amount of water generally varies inversely as the fuel ratio, be-
ing less than 1 per cent in some coals and as high as 25 per
cent in lignites. It will be noted that the so-called Smoke-

less coals given in the table of results all contain less than 1 per cent of moisture. The amount of moisture generally varies inversely as the fuel ratio. This statement is fairly well borne out by the results.

The ash in a coal simply occupies the place of so much combustible material and has not such a detrimental effect on the coal as the moisture excepting perhaps when the per cent of ash is large or it contains easily fusible constituents. In the first case, it may seriously retard combustion and in the second, it may form clinker upon the grate bars.

The amounts of moisture and ash in a coal are not shown by the fuel ratio and hence this does not serve to indicate its fuel value so much as its adaptability for specific purposes. For example, a coal for the production of gas should be high in volatile combustible matter and would therefore have a low fuel ratio.

The coking qualities of a coal are not altogether dependent upon its chemical composition, although the fuel ratio generally falls between 1.20 and 2.50. This does not mean however, that all coals having a fuel ratio falling within these limits will coke. The coal from the Pittsburg bed in the Connellsville district is taken as the standard coking coal with which all other coals are compared. In the same way, Pocahontas coal may be taken as a standard steam coal.

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SAMPLES.

A--Sherman Lump, Sherman, Ill.

B--Pittston Anthracite, Penn.

C--Youghioghney,   "

D--Farmington, W. Va., near Fairmont.

E--Kanawha District W. Va., Splint.

F---Pittsburg #8, Belmont Co., Ohio.

G--Elkins Smokeless Marion Co., W.Va.

H---Glen Block, Indiana.

I---Maryland Smokeless, Randolph Co., W. Va.

J---Powhatan Split, W. Va.

K--Collins Semi Block, Indiana.

L--Peerless Smokeless.

M--Jupiter Lump, So. Ill.

N--Pocahontas.

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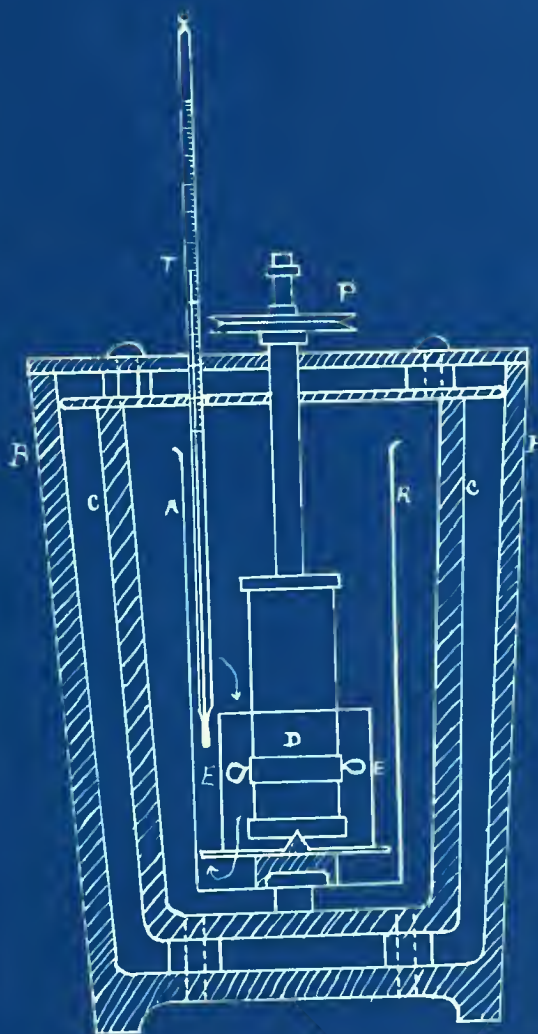| SAMPLE	MOISTURE	CHECK	ASH	CHECK	VOLATILE COMBUSTIBLE MATTER	CORRECTED FOR SULPHUR	CHECK	CORRECTED FOR SULPHUR	BRITISH THERMAL UNITS	SULPHUR	FIXED CARBON	CORRECTED FOR SULPHUR	CHECK	CORRECTED FOR SULPHUR	FUEL RATIO	CHECK
A	10.65	10.75	4.28	4.18	36.59	35.066	35.92	34.396	11154	3.048	48.48	46.956	49.15	47.626	1.339	1.384
B	4.34	4.23	4.00	4.07	4.65	—	—	—	—	NO COMBUSTION	87.010	—	—	—	18.711	—
C	1.45	1.30	2.76	2.70	37.79	36.798	40.03	39.038	13727	1.984	58.00	57.008	55.97	54.978	1.549	1.540
D	1.25	1.26	5.55	5.65	36.35	35.718	35.84	35.208	12270	1.364	56.85	56.218	57.25	56.618	1.573	1.608
E	1.88	1.84	4.90	4.87	37.92	36.461	36.01	34.551	13262	2.918	55.30	53.84	57.28	55.821	1.496	1.615
F	0.86	0.90	9.03	8.99	27.92	27.217	26.20	27.497	13045	1.406	62.19	61.487	61.91	61.207	2.259	2.226
G	0.90	0.89	8.66	8.70	28.84	27.75	27.94	26.85	13349	2.181	61.60	60.510	62.47	61.380	2.180	2.286
H	8.25	8.41	2.77	2.80	32.68	31.922	31.59	30.832	13541	1.516	56.30	55.542	57.20	56.442	1.739	1.830
I	0.99	0.95	6.29	6.28	28.94	25.244	28.80	28.104	14100	1.392	63.78	63.084	63.97	63.274	2.233	2.249
J	2.29	2.24	1.83	1.79	34.01	33.34	34.36	33.69	14347	1.340	61.87	61.20	61.61	60.94	1.835	1.808
K	7.92	7.85	2.69	2.84	38.22	36.471	36.14	34.501	13138	3.099	51.17	48.621	53.17	51.621	1.353	1.496
L	1.40	1.29	10.63	10.71	31.11	30.558	29.38	28.828	13324	1.104	56.86	56.308	58.62	58.068	1.842	2.014
M	6.55	6.42	7.10	7.23	37.05	35.85	37.51	36.31	12797	2.400	49.30	48.10	48.84	47.64	1.341	1.312
N	0.50	0.50	12.14	12.16	14.89	12.612	9.64	7.362	12797	4.547	72.47	70.192	77.70	75.422	5.406	10.244

Fig I.

Fig II.

THE PARR CALORIMETER.